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Abstract

We radio-tracked 27 white-tailed deer (*Odocoileus virginianus*) weekly for one year on Fort Chaffee, Arkansas, to investigate their seasonal home ranges and movements between hunted areas and refuges on this military base. This work resulted in 2,123 separate radiolocations, of which 85% (1,799) were suitable for use in home range analyses. We used the McPAAL computer package to estimate home range using the Harmonic Mean and minimum convex polygon (MCP) methods. Harmonic mean estimates were based on 95% contour lines. Home range size differed between the sexes and methods. Male home ranges were larger than those of females ($t = 3.32$, $P < 0.01$; harmonic mean) ($t = 2.07$, $P < 0.05$; MCP). Average home range sizes for males and females based on the harmonic mean method were estimated to be 483 ha and 181 ha, respectively, whereas home range estimates for males and females using the MCP method were 636 ha and 289 ha, respectively. The average home range size for all deer was 259 ha (harmonic mean) and 379 ha (MCP). We found no evidence that females restricted their home ranges during the fawning period. However, females' home ranges expanded during the breeding season, perhaps to find mates. Few deer moved to refuge areas that were off-limits to hunters during the hunting season.

Introduction

White-tailed deer (*Odocoileus virginianus*) generally occupy the same home range throughout their adult lives. This area must be large enough to encompass all the crucial resources necessary for survival and reproduction, yet small enough to allow a degree of familiarity that reduces energy expenditures and enhances survival (Marchinton and Hirth 1984). Consequently, home range size may change seasonally with changes in metabolic requirements, habitat productivity, foraging strategy, and reproductive status (McNab, 1963; Schoener, 1971; Clutton-Brock et al., 1982; Beier and McCullough, 1990; Relyea et al., 2000). Knowledge of the home range requirements of deer within a population can be useful to managers seeking to optimize the spatial distribution of food and cover within a management area. This research was conducted to provide information needed to make sound management decisions regarding deer habitat on Fort Chaffee. To better understand home range use in this population we sought to measure the mean size of annual and seasonal home ranges for adult males and females. We tested the following 4 hypotheses: (1) the annual home ranges of deer on Fort Chaffee would be smaller than those of deer in the Ozarks, (2) adult females would reduce home ranges during the fawning period when they tend to their fawns, (3) adult females would expand ranges during the breeding season, and (4) adult deer would seek the safety of non-hunted refuges within the study area during the hunting season.

Methods

Study Area.--Fort Chaffee is a 29,000 ha military base located approximately 18 km east of Fort Smith in western Arkansas. Most land consists of low east/west running hills typical of the Ouachita Mountain region and lower, more fertile land in the Arkansas River valley. Historically, the study area contained four major vegetation types: oak-hickory (*Quercus* spp.-*Carya* spp.) forests, oak-shortleaf pine (*Pinus echinata*) forests, bottomland hardwood forests, and tallgrass prairie (Braun 1950). With European settlement, farming and overgrazing reduced soil fertility and contributed to wind and water erosion (Sturdy et. al. 1991). Very little habitat improvement was implemented until Fort Chaffee was established in 1940; subsequently, much of the area was reforested by the Army. Current habitats on Fort Chaffee consist primarily of hardwood forests interspersed with early successional fields of various sizes. Excellent deer habitat is provided by extensive forest meadow ecotones, which are maintained by frequent fires ignited accidentally during training activities. This habitat supported a deer population that was approximately three times higher than those on the nearby Ozark and Ouachita National Forests at the time of this study (G. Wilks, Arkansas Game and Fish Commision, pers. comm.).

Hunting is prohibited on several areas of Fort Chaffee during the deer seasons because of their proximity to military activities. These areas comprise approximately 30% of the study area and may serve as refuges for deer during the hunting seasons.

Radio-tracking.--Deer were captured during January-

March 1995 using net guns fired from a helicopter or rocket-nets (Hawkins et al., 1968; Barrett et al., 1982). Each deer was immobilized with a mixture of 2.5 mg/kg of ketamine and 0.5 mg/kg of xylazine, aged (Severinghaus 1949), fitted with radio-collars (Advanced Telemetry Systems Inc, Isanti, MN 55040) and released at their capture site.

Each deer was located at least 3 times each week beginning 2 weeks after capture through January 1996. This 2-week delay allowed time for individuals to recover from the trauma of capture and return to normal daily routines. Individuals often were located more frequently, but access was sometimes restricted by military activities. Telemetry bearings were taken from 68 receiving stations with known UTM coordinates. A compass and yagi antenna were used to obtain the best bearing from receiver to radio-tagged deer.

Three or more bearings taken within a 15-minute interval were considered suitable for estimating a location (White 1990). Bearings were entered into the OTA computer program and the maximum likelihood method of triangulation was used to estimate locations and error ellipses (Lenth, 1981; Hoover, 1991). The average error ellipse of 100 random radio-locations was 1.6 ha. Azimuths derived during beacon tests had a mean error arc of $3.0 + 1.1^{o}$ (x + SD). An alpha-level of 0.05 was used in analyses, indicating that there was a 95% probability that a specific radio-location was found inside its error polygon.

The McPAAL computer package (Stowe and Blowhowiak, 1986) was used to estimate home range using the harmonic mean and minimum convex polygon (MCP) methods (Mohr, 1947; Dixon and Chapman, 1980). The harmonic mean analysis is based on the premise that most animals do not utilize their entire home range areas with equal intensity, but tend to occupy certain core areas within their home range with greater frequency (Hayne, 1949). Harmonic mean estimates were based on 95% contour lines, indicating a 95% probability that the deer will be found inside this line at any given time. We also calculated home range size using the MCP method because its prevalence in the deer literature allowed us to compare our results with previous studies. The shapes of individual home ranges were categorized as circular, elongated or irregular as described by Stumpf and Mohr (1962).

We tested whether adult females restricted their home ranges during the fawning season by comparing mean home range size during this period to home ranges prior to fawning. We considered the fawning period to be May 20-June 20, a period that encompassed the peak of fawning during the first half of June (Nelson 1990). Radiolocations recorded from April 15 to May 15 were used to calculate home ranges prior to fawning. We also tested whether females expanded their home ranges during the breeding season by comparing home range size during this period (November 1-December 15) to range size during the pre-breeding period (September 15-October 31).

Two-sample t-tests were used to test for differences in home range size between the sexes and between deer inhabiting refuge areas versus hunted areas of Fort Chaffee. Paired t-tests were used to test for differences in seasonal range size for females during the fawning versus pre-fawning periods and during the breeding versus pre-breeding periods (Spatz 1993).

Results

Twenty-seven deer (7 males, 20 females) were radio-collared and located on 2,123 occasions from February 1995 through January 1996. Of these, 1,799 (85%) locations were suitable for use in home range analyses. Home range size differed between the sexes and methods (Table 1). Male home ranges were larger than those of females ($t = 3.3$, $P < 0.01$; harmonic mean) ($t = 2.1$, $P < 0.05$; MCP) than those of females. Average home range sizes for males and females based on the 95% contour of the harmonic mean method were 483 ha and 181 ha, respectively, while home range estimates for males and females using the MCP method were 636 ha and 289 ha, respectively. The average home range size for all deer was 259 ha (harmonic mean) and 379 ha (MCP). Forty-eight percent of home ranges were elongated, with the remaining 52% exhibiting circular patterns.

The mean home range size for females did not differ significantly between the prefawning and fawning period ($t = 0.45$, $P = 0.66$). Home ranges during the fawning period averaged 37.7 ha, whereas pre-fawning ranges averaged 34.2

Table 1. Mean, standard error, and range of home range sizes of male and female whitetailed deer determined by two techniques on Fort Chaffee, Arkansas.

		Harmonic Mean (95% contour)			Minimum Convex Polygon		
Sex	**N**	**Mean**	**S. E.**	**Range**	**Mean**	**S. E.**	**Range**
Males	7	482.7 ha	88.2 ha	158-811 ha	636.4	233.4	178-1432 ha
Females	20	180.7 ha	22.5 ha	40-404 ha	288.7	100.8	55-963 ha

ha. However, we did find that two pregnant females made long moves (~14.0 km each) from their normal core areas to private land bordering Fort Chaffee near the time of parturition. Each deer remained in these new areas for several weeks, but then returned to their normal ranges.

Females extended their home ranges during the breeding period ($t = 2.1$, $P = 0.05$). The mean size of home ranges during the 6-week breeding period was 53.2 ha, whereas home ranges averaged 21.9 ha during the 6-week pre-breeding period. Our data suggest that this extension occurred regardless of whether the females occupied home ranges in refuges or in hunted sections of the study area.

Originally, we intended to compare the movements of males during the breeding season with those during the remainder of the year. However, of the 7 males that were radio-collared at the beginning of the study only 3 survived through the breeding season. Therefore, the sample size was too small to make a reasonable comparison.

Limited movement of deer occurred between the refuges and the hunted sections of Fort Chaffee. One male immigrated 7.5 km into a refuge and 1 female emigrated 3.5 km from a refuge into a hunted area, just prior to the deer season. Four females inhabited home ranges on the edges of refuges and moved periodically between the refuge and hunted portions of their range; however, we noticed no obvious movements by these individuals into the refuge portion of their ranges during the hunting season.

Discussion

In northern regions, cold temperatures and snow result in seasonal migrations by deer and larger home ranges (Verme, 1968; Ozoga and Gysel, 1972; Drolet, 1976; Nixon et al., 1991). In the south, snowfall is seldom deep enough or persists long enough to impede travel, so seasonal ranges are not necessary. Winter mast supplies are rarely covered by snow and some browse species remain green, so deer do not have to move far to acquire food. We saw no seasonal movements among deer on Fort Chaffee; these deer exhibit fidelity to year-round home ranges as described by Progulske and Baskett (1958) and Marchington and Jeter (1967).

The size of home ranges of adult deer can vary from 45 to 2500 ha depending on sex, age, and habitat quality (Demarais et al., 2000). Annual home ranges of adult females is typically about 50% that of adult males. In the mixed pine/hardwood forests of the Arkansas Ozark Highlands, Cartwright (1975) calculated that annual home ranges averaged 520 ha using the MCP method. The mean size of males' ranges was 627 ha, whereas females averaged 453 ha. He speculated that these large ranges were a response to sparse food resources.

We anticipated that home ranges on our study area would be smaller than in the Ozarks because we thought that the interspersion of open fields and forests provided higher quality yearround habitat than Ozark forests. However, males on Fort Chaffee used home ranges that were very similar in size to those reported by Cartwright (1975) for males in the Ozarks; whereas, females on Fort Chaffee occupied home ranges that were 40% smaller than those in the Ozarks. These patterns may reflect the different factors that influence home range size for males and females. Male deer tend to expand their home ranges during the breeding season to increase breeding opportunities; this expansion is consistent across a wide range of population densities (Marchinton and Hirth, 1984; Beier and McCullough, 1990; Labisky and Fritzen, 1998). Therefore, home range size tends to be influenced most by the availability of mates. In contrast, the size of females' ranges may correlate closely with the density of resources (e.g. food and cover) required for their survival and that of their offspring. We speculate that males on Fort Chaffee cover as much area finding receptive females as males in the Ozarks, but females use smaller ranges because resources are more abundant on the base and they can meet their needs in a smaller area.

Approximately half of the home ranges on Fort Chaffee were elongated in shape and half were circular. Previous studies have shown that the configuration of deer ranges are usually elongated when calculated using the MCP method, but circular and irregular ranges have been reported (Marchington and Jeter, 1967). Linear home ranges provide maximum access to available resources and minimize movement and energy expenditure when food, cover, and water are distributed among diverse habitats (Stumpf and Mohr, 1962; Marchinton and Hirth, 1984). However, in more uniform habitat with an interspersion of resources, deer tend to move out in all directions from a central point resulting in circular patterns (Hood, 1971).

Smaller female ranges during the fawning season, when detected, have usually been attributed to the limited mobility of fawns. Ozoga et al. (1982) reported that does in Michigan greatly reduced the size of their home ranges for the first month postpartum and vigorously defended the area surrounding their fawn(s). They postulated that females actively defend an unchanging, well-defined area around her fawn. The females that they studied were in a fenced enclosure which prohibited movements. In contrast, Schwede et al. (1994) argued that females defended only a constantly changing space immediately around each fawn. We did not find reductions in home ranges during the 4-week perinatal period and speculated that this may relate to the patchy distribution of suitable cover for bedding fawns. Large meadows dominate much of the study area and during spring and summer these frequently bum due to accidental or prescribed fires resulting in short grasses that provide little cover. Consequently, females may be forced to

move fawns over relatively large areas to find suitable bedding sites resulting in relatively large home ranges during the fawning season.

Previous studies have shown that females may either restrict or expand their home ranges during the breeding season depending on the availability of mates (Holzenbein and Schwede, 1989; Labisky and Fritzen, 1998). When breeding males are abundant, females may limit their activities to core areas within their home range. This "sit-and-wait" strategy may be adaptive if it increases successful mating by providing predictable access to receptive females by mobile males searching for mates. However, females may be expected to increase their movements and shift to an "active search" strategy to facilitate mating when males are sparse. Holzenbein and Schwede (1989) proposed that the extent of female movements during the breeding season could be used as an index of the availability of males; increased movements by a large proportion of adult females would indicate a scarcity of breeding males in the population.

Labisky and Fritzen (1998) reported that females on a Florida study area with sparse males increased their movements during the breeding season in an apparent attempt to find mates. However, they acknowledged that because the breeding season and hunting seasons coincided, increased movements may have been due to disturbance by hunters. On Fort Chaffee, the mean home range size of females inhabiting hunted areas expanded during this period as might be expected if hunter disturbance caused increased movements. However, the home ranges of all 10 females inhabiting unhunted, refuge areas also increased during the breeding season suggesting that hunter disturbance was not the cause. We do not believe that range expansion during this period is caused by searches for food because forage, mast, and supplemental food plots were available throughout the study area through December. Rather, we speculate that the long history of bucks only hunting on Fort Chaffee combined with high mortality rates among adult males caused by poaching (Humphreys, 1996) may have reduced the proportion of breeding males in the population to a density which forced females to adopt an active search strategy for males during the breeding season and that this accounted for the home range expansion during the breeding season. Adult males comprised only 15% of the deer legally harvested on Fort Chaffee from 1991-95 (Nelson and Phillips 1998).

We also speculate that deer might actively move to the protection of the nonhunted refuge areas during the hunting seasons. Hunting on these areas has been prohibited for many years due to the danger posed by military activities. However, we detected no systematic movement of deer into refuge areas. Two deer made long movements during the hunt; one into a refuge and another out of a refuge. Females with home ranges encompassing both hunted and refuge sections were as likely to found in either section during the hunting season.

Based on our results, habitat improvements for deer should be conducted at a spatial scale that provides an interspersion of life requisites (winter forage, cover, water) every 180 ha. Providing resources (or improving those already present) within the average female's home range size will ensure that individuals of both sexes have access to these resources and aid in improving the condition of Fort Chaffee deer.

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